REMARKS

Claims 1, 2 and 4-22 were pending in the application. Claim 20 is allowed. Claims 1-2, 4-19, 21-22 stand rejected. Claims 5, 14, and 18 were cancelled. Claims 1, 4, 9, 15-17, 19, and 22 were amended. Claim 23-25 were added.

Claims 1 and 22 stand rejected under 35 U. S.C. 102(b) as being anticipated by R.T. Whitaker, J. Gregor, P.F. Chen, University of Tennessee, "Indoor Scene Reconstruction from Sets of Noisy Range Images", published in 1999 at IEEE's Second International Conference on 3-D Imaging and Modeling (hereinafter 'renowned institution'). The rejection stated:

> "With regard to claim 1, 'renowned institution' discloses a method for deriving a 3-D panorama from a plurality of images of a scene generated by a range imaging camera that produces ambiguities in range information (see the first paragraph of the 'Introduction': The reference describes deriving a 3-D model of an 'entire scene' (i.e. a panorama). The reference further describes that the images are 'laser range images' or 'LADAR data'. The applicant's disclosure (see paragraph [0027], inter alia) explains that the claimed range imaging camera that produces the range information is a laser radar. Accordingly, the reference anticipates this limitation.
>
> "'Renowned institution' further discloses acquiring a plurality of adjacent, overlapping range images (see Figure 4a-b).
>
> "'Renowned institution' further discloses estimating a relative range difference between adjacent range images to provide an estimated constant offset between the adjacent images; and optimizing said estimated constant offset to provide an optimized constant offset (page 1, col. 2, final paragraph, the reference describes determining a distance between views. The reference further elaborates on the view registration (or pose determination, see pg. 1, col. 2, the first two lines of the second paragraph) method and the plane offsets (pg. 4 - col. 2) by defining variables $\omega 1$, and $\omega 2$, which are plane offsets. This shows a constant offset between adjacent range images as required by the claim. The above-cited passage also shows an initial estimate of range difference which is subsequently optimized by a singular value decomposition operation to make the estimate more robust. This is in accord with applicant's own disclosure, which teaches using singular value decomposition for optimization of range estimates (applicant's disclosure paragraph [0034])."

Claim 1 has been amended to state:

1. A method for deriving a three-dimensional panorama from a plurality of images of a scene generated by a range imaging camera of the type that produces ambiguities in range information, said method comprising the steps of:

acquiring a plurality of adjacent images of the scene, said adjacent images each having a known capture position defining a known spatial relation between said adjacent images, wherein there is an overlap region between the adjacent images and at least some of the adjacent images are range images, said range images each having relative range values, said range images differing by said known spatial relation and an unknown relative range difference;

estimating said relative range difference between the adjacent range images to provide an estimated constant offset;

optimizing said estimated constant offset to provide an optimized constant offset; and

deriving a three-dimensional panorama from said range images and said optimized constant offset.

The language of Claim 1 is supported by the application as filed, notably the original claims and at page 10, line 25 to page 11, line 8; page 17, line 23 to page 19, line 2; page 3, lines 3-25; page 5, lines 15-19; page 15, lines 2-7; page 15, lines 13-14.

Claim 1 requires acquiring adjacent range images having known capture positions defining a known spatial relation. The range images each have relative range values that differ by the known spatial relation and an unknown relative range difference. The relative range difference is estimated to provide an estimated constant offset, which is then optimized. The nature of the ambiguity in range information is described in the application:

"This ambiguity arises because the phase values returned by the SRI system do not contain any information about absolute distance to the camera. The information captured by the SRI system is only sufficient to generate relative range values, not absolute range values. Therefore, the absolute range values differ by the values computed and returned by the SRI system in the range images by some unknown constant. In general, the unknown constant for a given range image is not the same as the unknown constant for another range image.

This presents a problem when attempting to merge/stitch two adjacent range images captured from the SRI system. If the unknown constants are not the same, it will be impossible to continuously merge the two images." (application, page 3, lines 16-25)

"In order to determine the difference in constant range offsets between subsequent images, we employ an optimization procedure. Referring to Figures 5A and 5B, we compare adjacent 3D range images 500 (left) and 502 (right). If we consider that pixel (x_1,y_1) 504 in the left image 500 and pixel (x_2,y_2) 506 in the right image contain relative range values (say d_1 and d_2, respectively) to the same real world point 306, then we know by definition that d_1 is measured orthogonally to the left image plane 500, and that d_2 is measured orthogonally to the right image plane 502. In addition, one caveat of the SRI cameras is that 3D range values are known only in relation to one another, not as absolute distances to the image plane. Therefore, it is necessary to recover corrected relative scene spatial information and, consequently, there is an unknown constant offset that must be accounted for in order to correctly compare the 3D range values in the left 500 and right 502 images.

"Figure 5B illustrates the difference in the local coordinate systems that describe the range values in the left 500 and right 502 images. <u>Looking down the nodal axis of the SRI camera</u>, 508 is parallel to the x-axis of the left image 500, and 510 is parallel to the x-axis of the right image 502. The real world point 306 projected into both images is found to have a 3D range value 512 of d_1 in the left image 500 and a 3D range value 514 of d_2 in the right image 502. <u>The angle 518 between the image planes is known *a priori*, and is denoted θ.</u> If the 3D range values d_1 and d_2 are known absolutely, then it can easily be shown that:

$$d_2 = \frac{d_1}{f}(\beta \sin\theta + \cos\theta), \qquad \text{(Eq. 12)}$$

where f is the focal length of the SRI camera and β 516 is the horizontal distance from the center of the image to the pixel containing the projection of 306. Since the 3D range values d_1 and d_2 are not known absolutely, the relationship between d_1 and d_2 becomes:

$$d_2 = \frac{d_1 + \alpha}{f}(\beta \sin\theta + \cos\theta), \qquad \text{(Eq. 13)}$$

where α is the unknown constant offset between the relative 3D range values." (application, page 15, lines 8-22; emphasis added)

In contrast, 'renowned institution' deals with range images having ambiguity in capture position. 'Renowned institution' states, in section "3.1 Solving for Relative Pose":

> "This section shows the derivation of the equations needed for computing the camera pose directly from pairs of plane surface normals and offsets. Let $(\mathbf{n}_{1i},\omega_{1i})$ and $(\mathbf{n}_{2i},\omega_{2i})$ refer to a pair of corresponding planes. The problem is then to determine rotation matrix **R** and translation vector **t** such that if a point **p** lies a distance d from the plane $(\mathbf{n}_{1i},\omega_{1i})$ then point $\mathbf{q} = \mathbf{R}\mathbf{p} + \mathbf{t}$ is guaranteed to lie the same distance from the plane $(\mathbf{n}_{2i},\omega_{2i})$." (emphasis added)

'Renowned institution', estimates and optimizes a spatial relation between range images that relates to the difference in capture positions.

Claim 22 is allowable on the same grounds as Claim 1.

Claim 16 stands rejected under 35 U.S.C. 103 (a) as being unpatentable over 'renowned institution'. The rejection incorporated the arguments as to Claims 1 and 22 and further stated:

> "'Renowned institution' further discloses deriving a 3D panorama from said range images and said optimized constant offset. This was discussed above with respect to the preamble of claim 1. As was stated, the 'entire scene' is analogous to the claimed 'panorama'. These two terms are definitionally equivalent (see websters dictionary).
>
> "'Renowned institution' further discloses providing offset data for the range images (pg. 1 col. 2., final paragraph: The reference describes determining 'distances between views'. This is analogous to providing offset data as recited in the claim.) in order to recover corrected relative scene spatial information (pg. 1 col. 2, lines 4-7: The reference describes registering separate viewpoints and then integrating those viewpoints. This is analogous to recovering the relative scene spatial information. Furthermore, the second paragraph of the right column of page 2 describes a smoothing preprocessing operation is performed before all of the other processes. Smoothing qualifies as a type of 'correction'; therefore the reference also meets the claimed limitation of `corrected relative scene spatial information.').
>
> "The 'renowned institution' further discloses applying this offset data to correct for ambiguities in the relative ranges of the range images, thereby

providing corrected range images. As was stated in the paragraph above, the 'renowned institution' discloses determining range differences between adjacent range images. These offsets are analogous to the ambiguities recited in the claim (also see pg. 2 - col. 1 - final paragraph: this passage makes explicit mention of the ambiguities associated with the range images). The passage cited in the above paragraph shows how the range differences are used in the determination of a translation, which aligns, registers, or fits these images together, thereby providing corrected range images.

"'Renowned institution' inherently discloses a computer program product because a computer performing a process is disclosed at pg. 7.

"Regarding the additional limitation of "automatically providing offset data": 'renowned institution' does not anticipate this limitation because it requires user input. However, 'renowned institution' does expressly state that "Our ultimate goal is a totally automated system, and to this end we have designed the system to rely on user input only for the scan-to-scan plane correspondences, which we hope to automate in future implementations. It would have been obvious to one reasonably skilled in the art at the time of the invention to follow the suggestion of the 'renowned institution' and totally automate the existing system. Such a modification would have allowed for a system that could be executed without the added cost of user interaction."

Claim 16 states:

16. A computer program product for deriving a three-dimensional panorama from a plurality of images of a scene generated by a range imaging camera of the type that produces ambiguities in range information, said computer program product comprising: a computer readable storage medium having a computer program stored thereon for performing the steps of:

(a) accessing a plurality of adjacent images of the scene, said adjacent images each having a known capture position defining a known spatial relation between said adjacent images, wherein there is an overlap region between the adjacent images and at least some of the adjacent images are range images, said range images each having relative range values, said range images differing by said known spatial relation and an unknown relative range difference;

(b) automatically providing offset data for the range images in order to recover corrected relative scene spatial information, wherein the step of providing offset data further comprises:

(i) estimating said relative range difference between the adjacent range images to provide an estimated constant offset;

(ii) optimizing said estimated constant offset to provide an optimized constant offset;

(iii) applying the optimized constant offset to at least one of adjacent range images to correct for ambiguities in the relative ranges of the range images, thereby providing corrected range images; and

(c) deriving a three-dimensional panorama from the corrected range images.

Claim 16 is supported and allowable on the grounds discussed above in relation to Claim 1 and as follows. The rejection argues that 'renowned institution' suggests automatically providing offset data such that it would have been obvious to one reasonably skilled in the art at the time of the invention to totally automate the existing system. "Renowned institution' does state:

> "Our ultimate goal is a totally automated system, and to this end we have designed the system to rely on user input only for the scan-to-scan plane correspondences, which we hope to automate in future implementations." (renowned institution, section 3)

This suggestion represents recognition of the problem, but no solution. Based upon 'renowned institution', one of skill in the art would not know how to proceed. 'Renowned institution' states "we hope to automate". This teaches or suggests that a solution to the problem was unknown to persons of skill in the art, since the solution was unknown to the authors of 'renowned institution' at the time of publication.

Claims 2, 4-5, 7-8, 14-15, 17-18, and 21 stand rejected under 35 U.S.C. 103(a) as being unpatentable over the combination of the 'renowned institution' and Hsieh et al. (USPN 6,011,558).

Claims 5, 14, and 18 were cancelled.

Claims 2 and 21 are allowable as depending from Claim 1.

The rejection relies upon the arguments as to Claims 1, 16, and 22 above further states:

Referring to claim 4, Hsieh further discloses that the images are acquired by horizontally rotating a camera about its optical center (Hsieh col. 1 lines 17-20). The only type of axis that a camera can be 'horizontally rotated about' is a vertical axis. Thus, the additional limitation of claim 4 is met by Hsieh. With regard to the claim 4 limitation of (X,Y,Z) coordinates and/or images, this limitation has already been addressed with respect to the claim 2 limitation of a 3D coordinate and/or image. It is well known that (X,Y,Z) coordinates are merely a synonym for 3D coordinates. All of the 3D limitations were met by the 'renowned institution' reference.

Claim 4 states:

4. A method for deriving a three-dimensional panorama from a plurality of images of a scene generated from a range imaging camera of the type that produces ambiguities in range information, said method comprising the steps of:

acquiring a plurality of images of the scene by rotating the camera about a Y-axis (vertical axis), wherein there is an inter-overlap region and known spatial relation between adjacent images and at least two of the adjacent images are range images, said range images each having relative scene spatial information, said range images differing by said known spatial relation and an unknown relative range difference;

estimating said relative range difference to provide an estimate;

automatically optimizing said estimate to provide an optimized constant range offset;

automatically applying said constant range offset to one of said range images to provide corrected relative scene spatial information (X,Y,Z) of one of said range images with respect to a first local XYZ coordinate system and relative scene spatial information (X,Y,Z) of the other of said range images with respect to a second local XYZ coordinate system;

selecting a reference three-dimensional world coordinate system against which spatial information of the scene can be correctly presented;

transforming the corrected relative scene spatial information (X,Y,Z) from each of the local three-dimensional coordinate systems of each

of the images to the selected reference three-dimensional world coordinate system, thereby providing transformed (X,Y,Z) images;

warping the transformed (X,Y,Z) images onto a cylindrical surface, and forming a plurality of warped (X,Y,Z) images;

registering adjacent warped (X,Y,Z) images; and

forming a three-dimensional (X,Y,Z) panorama using the warped (X,Y,Z) images.

Claim 4 is supported by the application, as filed, in the same manner as Claim 1.

Claim 4 is allowable on grounds like those discussed in relation to Claim 1. Claim 4 requires that range images having relative scene spatial information, differ by a known spatial relation and an unknown relative range difference. The range difference is estimated and the result is optimized. 'Renowned institution', as discussed above, does not disclose this feature. Assuming for the sake of argument, that the references could be combined and that the combination of "horizontally rotating a camera about its optical center" of Hsieh with 'renowned institution' would teach adjacent range images each having a known capture position defining a known spatial relation between the adjacent images, that combination would still not teach the claimed invention. The combination would no longer require a solution to the problem of pose determination. The camera poses would be known. This would render the procedure of section 3.1 of 'renowned institution' unnecessary and make the combination of Hsieh and 'renowned institution' even more unlike the claimed invention than 'renowned institution' by itself.

Claims 7-8 are allowable as depending from Claim 4.

Claims 15 and 17 are supported and allowable on the grounds discussed above in relation to Claim 1.

Claim 6 stands rejected under 35 U.S.C. 103 (a) as being unpatentable over the combination of 'renowned institution' and Hsieh, and further in view of Ray (USPN 6,023,588). Claim 6 is allowable as depending from Claim 4.

Claims 9 and 19 stand rejected under 35 U.S.C. 103(a) as being unpatentable over the combination of renowned institution' and Hsieh as applied to claim 4 above, and further in view of Lipscomb et al. (USPN 5,796,386). Claims 9 and 19 are allowable as depending from Claims 4 and 17, respectively.

Claims 10-11 stand rejected under 35 U.S.C. 103 (a) as being obvious over the combination of 'renowned institution' and Hsieh as applied to claim 4 and

further in view of Ray et al. (U.S. Patent No. 6,118,946 B 1). Claims 10-11 are allowable as depending from Claim 4.

Claims 12 and 13 are rejected under 35 USC 103(a) as being obvious over the combination as applied to claim 10 above, and further in view of Ray (USPN 6,456,793). Claims 12-13 are allowable as depending from Claim 4.

The Office Action indicated that if claim 1 were found allowable, claim 22 would be objected to under 37 CFR 1.75 as being a substantial duplicate thereof. Claim 22 has been amended to differ from Claim 1 and now states:

> 22. A method for deriving a three-dimensional panorama from a plurality of images of a scene generated by a range imaging camera of the type that produces ambiguities in range information, said method comprising the steps of:
>
> acquiring a plurality of image bundles of the scene, said image bundles each having a known capture position, each said image bundle having a plurality of phase images each having relative range values, said phase images of adjacent said image bundles differing by a known spatial relation defined by respective said known capture positions and differing by an unknown relative range difference;
>
> estimating ~~a~~ said relative range difference between adjacent said range images to provide an estimated constant offset between the adjacent images;
>
> automatically optimizing said estimated constant offset to provide an optimized constant offset; and
>
> deriving a three-dimensional panorama from said range images and said optimized constant offset.

Claim 22 is supported and allowable on the grounds discussed above in relation to Claim 1.

Added Claims 23-25 state:

> 23. The method of claim 22 wherein said estimating further comprises using said known spatial relation.
>
> 24. The method of claim 1 wherein said estimating further comprises using said known spatial relation.
>
> 25. The method of claim 1 wherein said known spatial relation is an angular offset.

Claims 23 and 24-25 are allowable as depending from Claims 22 and 1, respectively, and as follows.

Claims 23-24 are supported by the application as filed, notably at page 15, lines 8-22. 'Renowned institution' lacks a known spatial relation and, thus, could not use such in estimating an unknown relative range difference. The combination of 'renowned institution' and Hsieh would, as discussed above, arguably have the known spatial relation, but would then not use the procedure for solving relative pose, since the relative poses would be known.

Claim 25 is supported in the same manner as Claims 23-24.

It is believed that these changes now make the claims clear and definite and, if there are any problems with these changes, Applicants' attorney would appreciate a telephone call.

In view of the foregoing, it is believed none of the references, taken singly or in combination, disclose the claimed invention. Accordingly, this application is believed to be in condition for allowance, the notice of which is respectfully requested.

Respectfully submitted,

Attorney for Applicant(s)
Registration No. 30,700

Robert Luke Walker/amb
Rochester, NY 14650
Telephone: (585) 588-2739
Facsimile: (585) 477-1148

\